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(54) **SYSTEM AND METHODS FOR THE UNIVERSAL INTEGRATION OF PLANT FLOOR ASSETS AND A COMPUTERIZED MANAGEMENT SYSTEM**

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This patent is subject to a terminal disclaimer.

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(22) Filed: **Jan. 18, 2013**

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(51) **Int. Cl.**

G05B 13/02	(2006.01)
H04L 12/24	(2006.01)

(52) **U.S. Cl.**
CPC ***G05B 13/02*** (2013.01); *H04L 41/0213* (2013.01); *H04L 41/0226* (2013.01); *H04L 41/06* (2013.01)

(58) **Field of Classification Search**
CPC .. H04L 41/06; H04L 41/0213; H04L 41/0226
USPC 709/217, 224, 246; 340/501, 679
See application file for complete search history.

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(57) **ABSTRACT**

A server platform and a method to integrate a plurality of diverse plant floor equipment with at least one computerized management system in a manufacturing operational or maintenance system. The server platform includes a plurality of plant floor drivers adapted to communicatively interface with a plurality of diverse plant floor data sources. The server platform further includes at least one computerized management system driver adapted to communicatively interface with the at least one computerized management system. The server platform also includes a message translator adapted to broker communication between the plant floor data sources and the at least one computerized management system using an open standard. The server platform, using the open standard, enables a universal enterprise type taxonomy across the plant floor data sources and the at least one computerized management system.

42 Claims, 10 Drawing Sheets

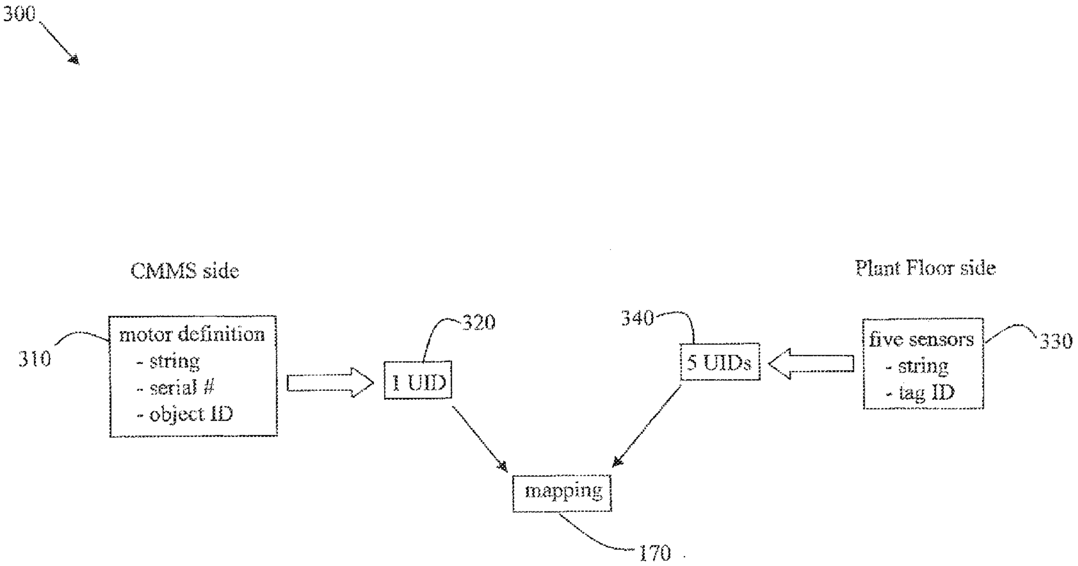


FIG. 1

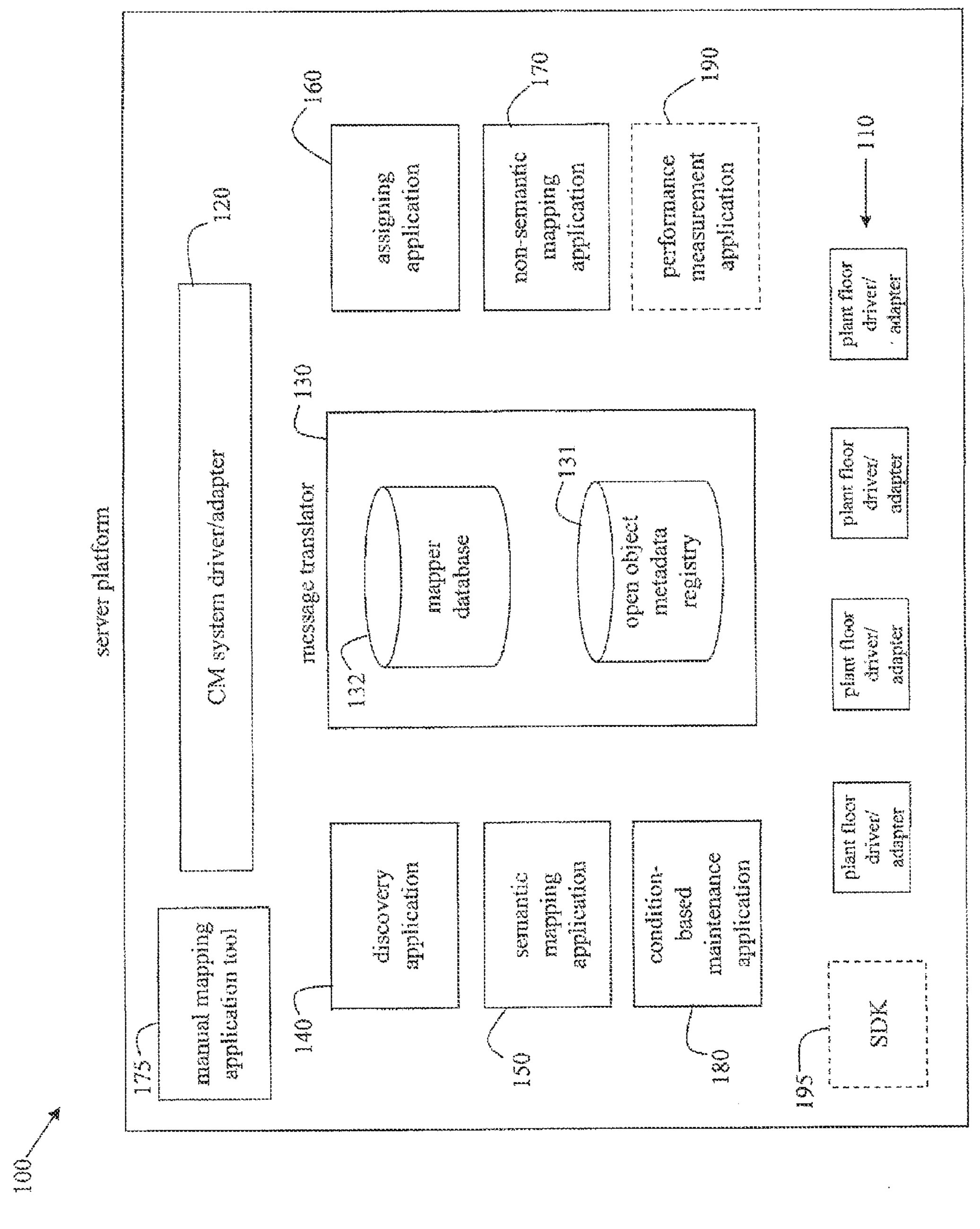

100
server platform
175
manual mapping application tool
120
CM system driver/adapter
140
discovery application
150
semantic mapping application
180
condition-based maintenance application
130
message translator
132
mapper database
131
open object metadata registry
160
assigning application
170
non-semantic mapping application
190
performance measurement application
195
SDK
plant floor driver/adapter
plant floor driver/adapter
plant floor driver/adapter
plant floor driver/adapter
110

FIG. 2

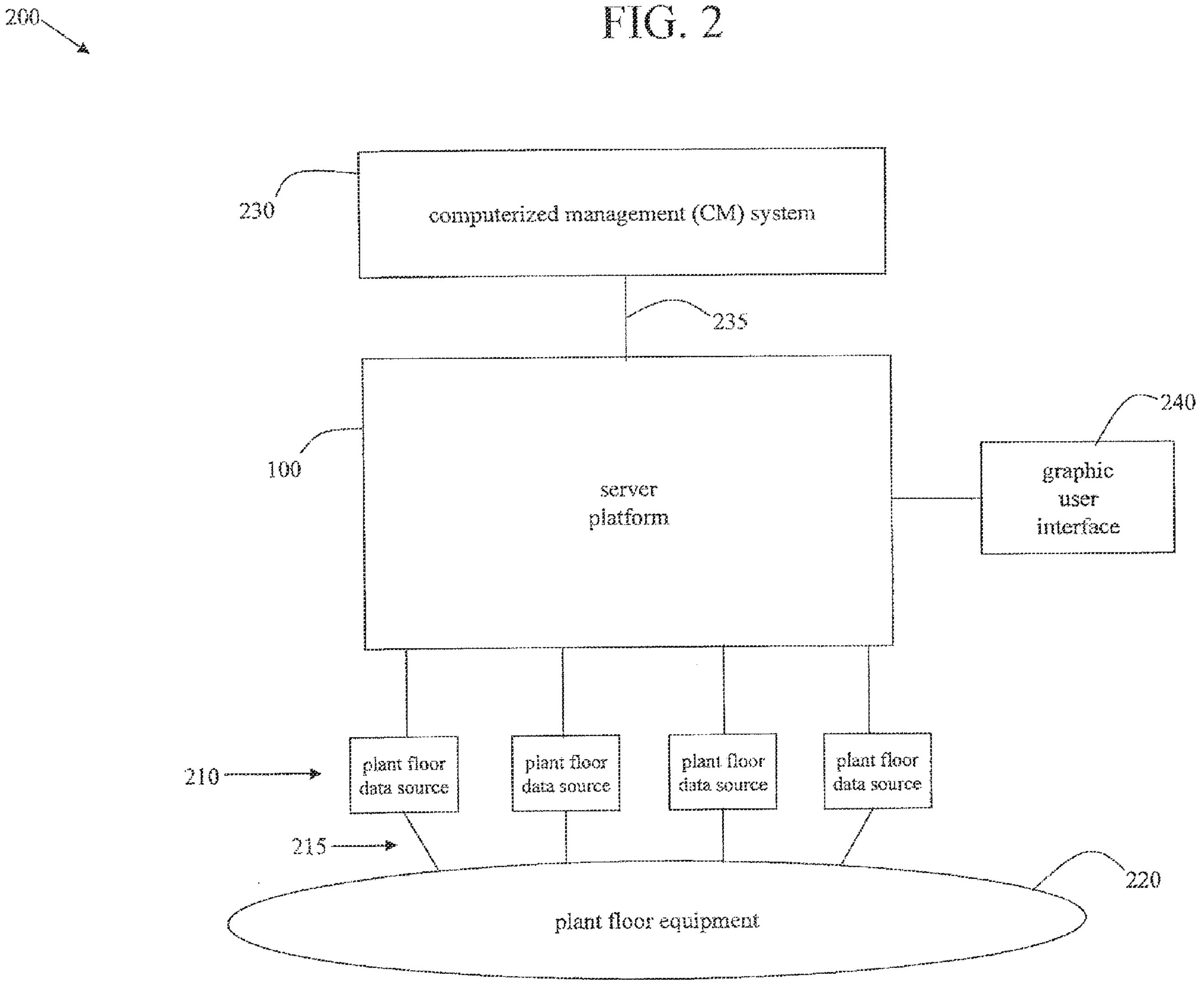

200
230
computerized management (CM) system
235
100
server
platform
240
graphic
user
interface
210
215
plant floor
data source
plant floor
data source
plant floor
data source
plant floor
data source
220
plant floor equipment

FIG. 3

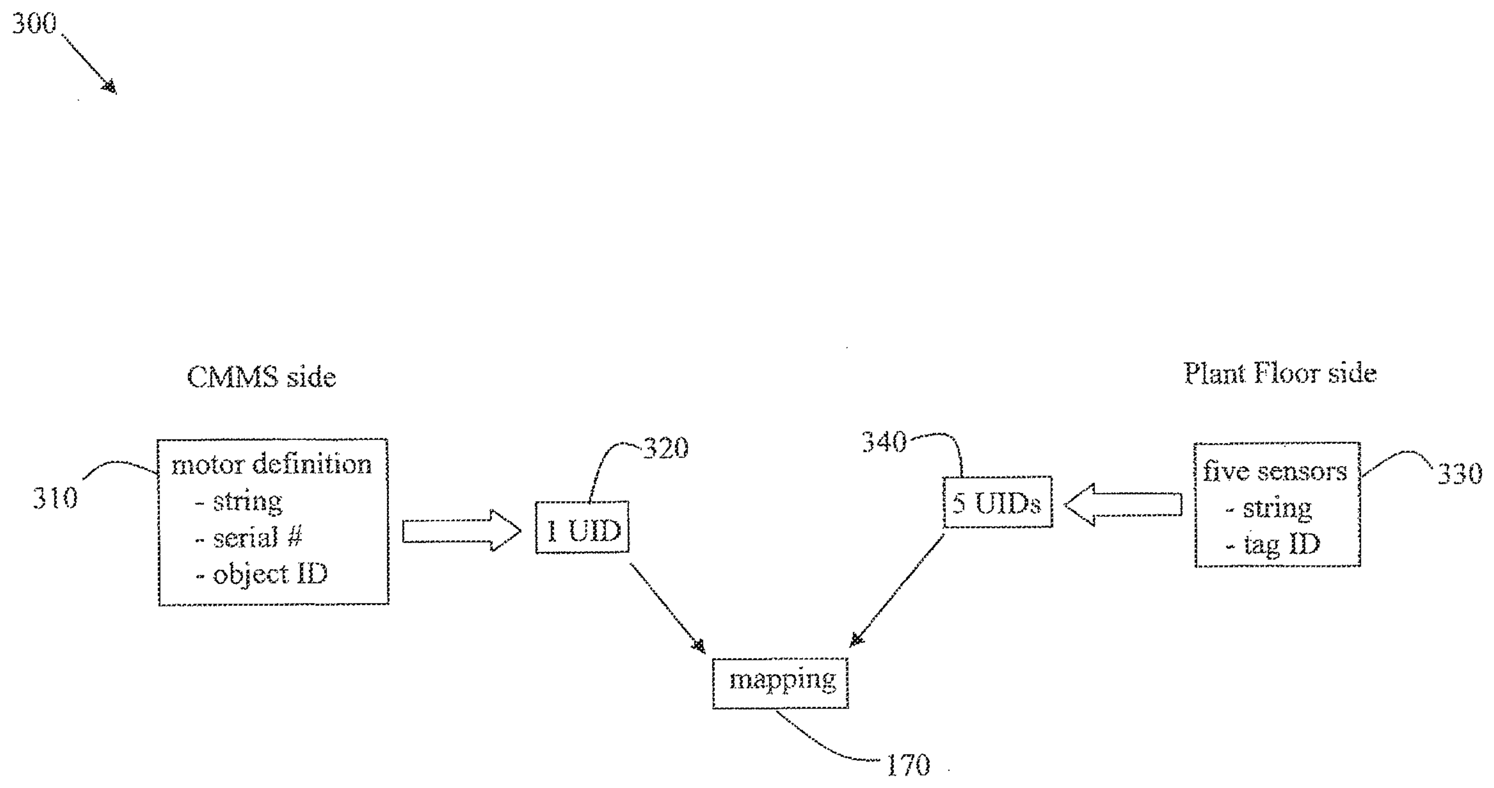

300
CMMS side
Plant Floor side
310
motor definition
- string
- serial #
- object ID
320
1 UID
340
5 UIDs
330
five sensors
- string
- tag ID
mapping
170

FIG. 4

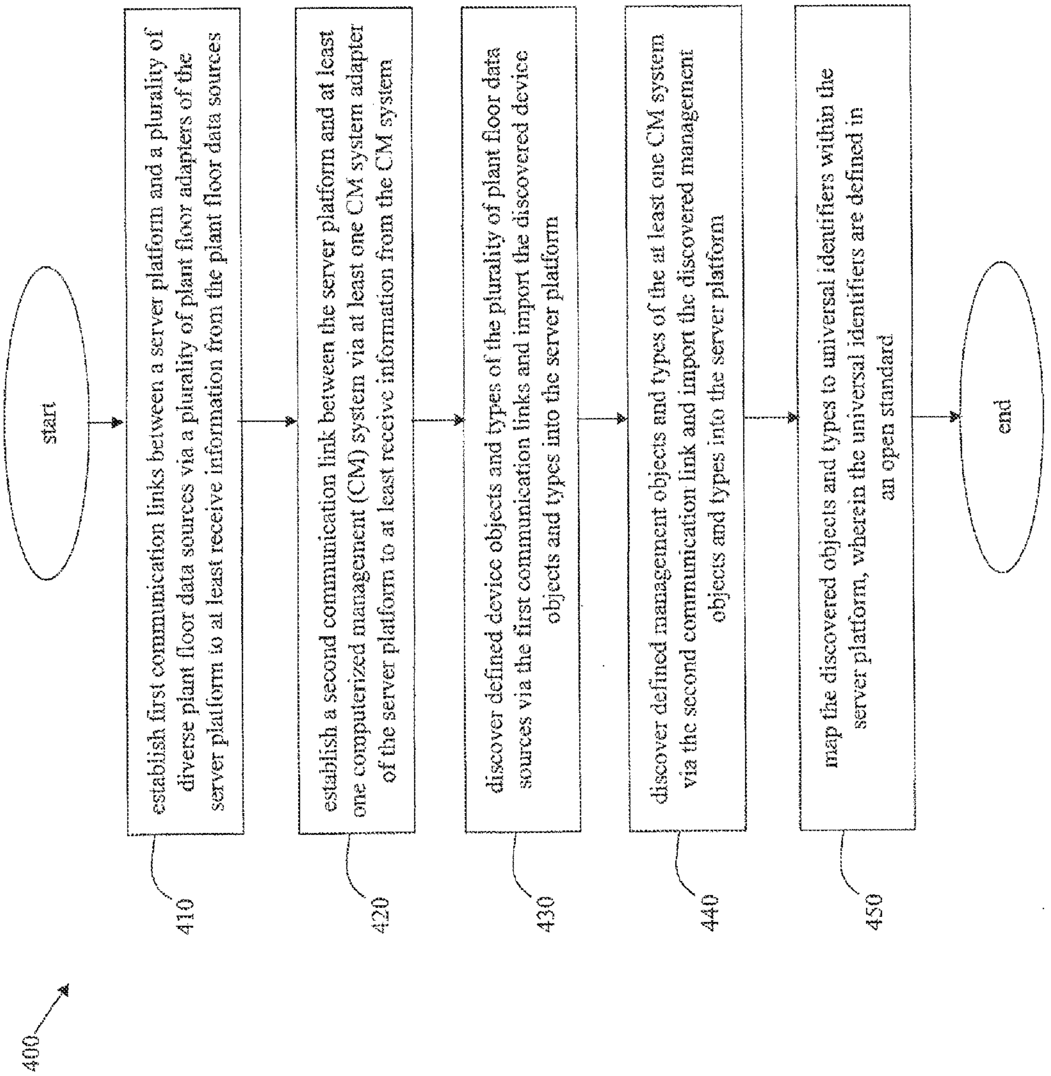
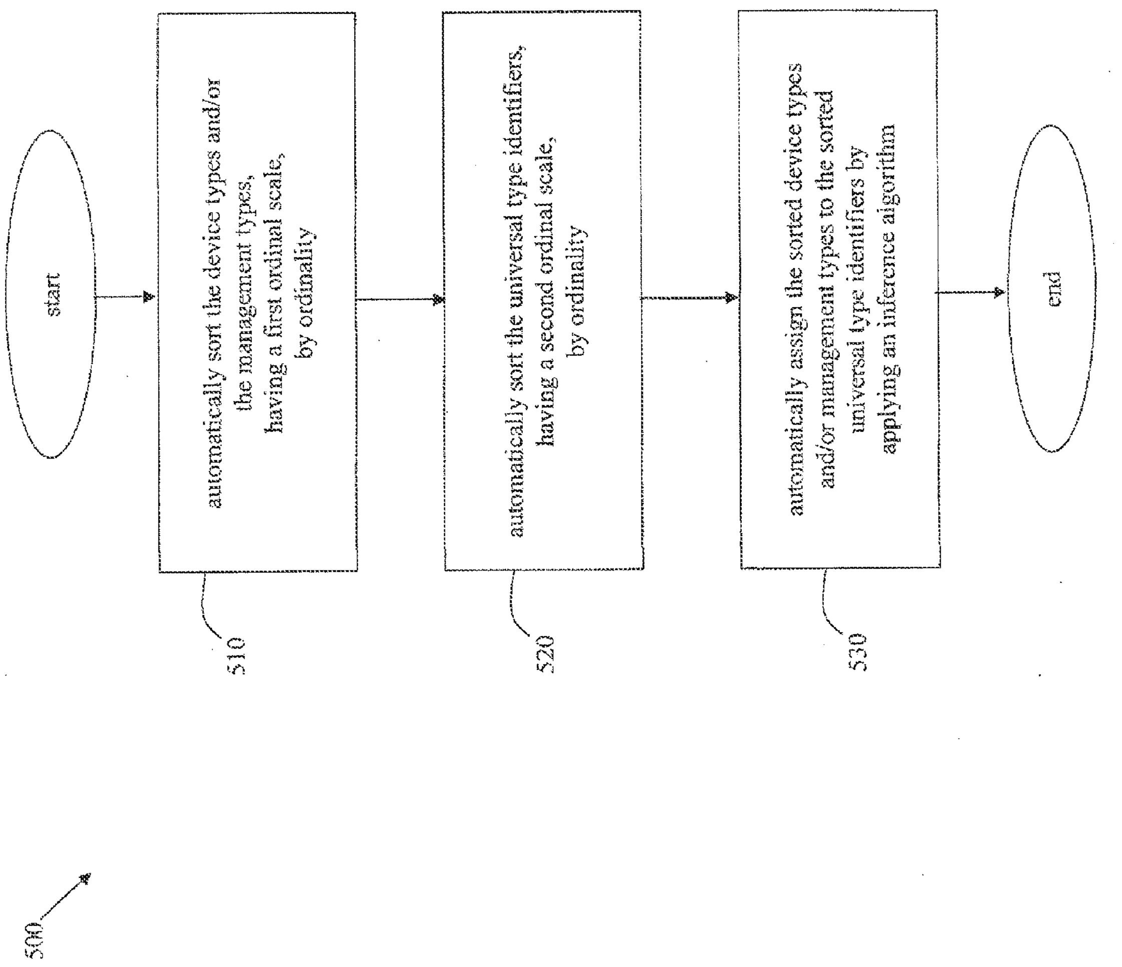

400
start
establish first communication links between a server platform and a plurality of diverse plant floor data sources via a plurality of plant floor adapters of the server platform to at least receive information from the plant floor data sources
410
establish a second communication link between the server platform and at least one computerized management (CM) system via at least one CM system adapter of the server platform to at least receive information from the CM system
420
discover defined device objects and types of the plurality of plant floor data sources via the first communication links and import the discovered device objects and types into the server platform
430
discover defined management objects and types of the at least one CM system via the second communication link and import the discovered management objects and types into the server platform
440
map the discovered objects and types to universal identifiers within the server platform, wherein the universal identifiers are defined in an open standard
450
end

FIG. 5


start
automatically sort the device types and/or the management types, having a first ordinal scale, by ordinality
automatically sort the universal type identifiers, having a second ordinal scale, by ordinality
automatically assign the sorted device types and/or management types to the sorted universal type identifiers by applying an inference algorithm
end
510
520
530
500

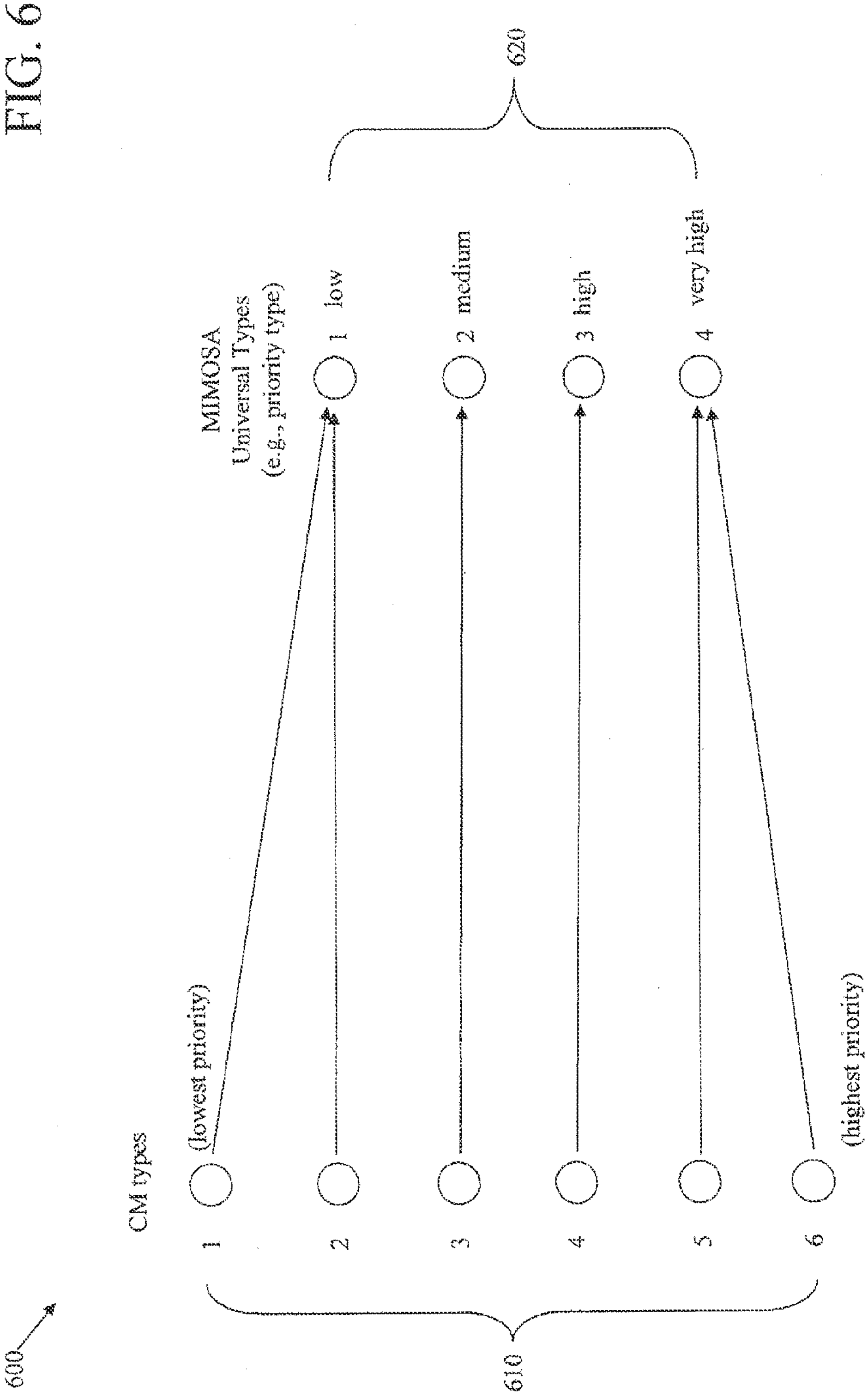

600
CM types
1
(lowest priority)
2
3
4
5
6
(highest priority)
610
MIMOSA
Universal Types
(e.g., priority type)
1 low
2 medium
3 high
4 very high
620

FIG. 6

FIG. 7

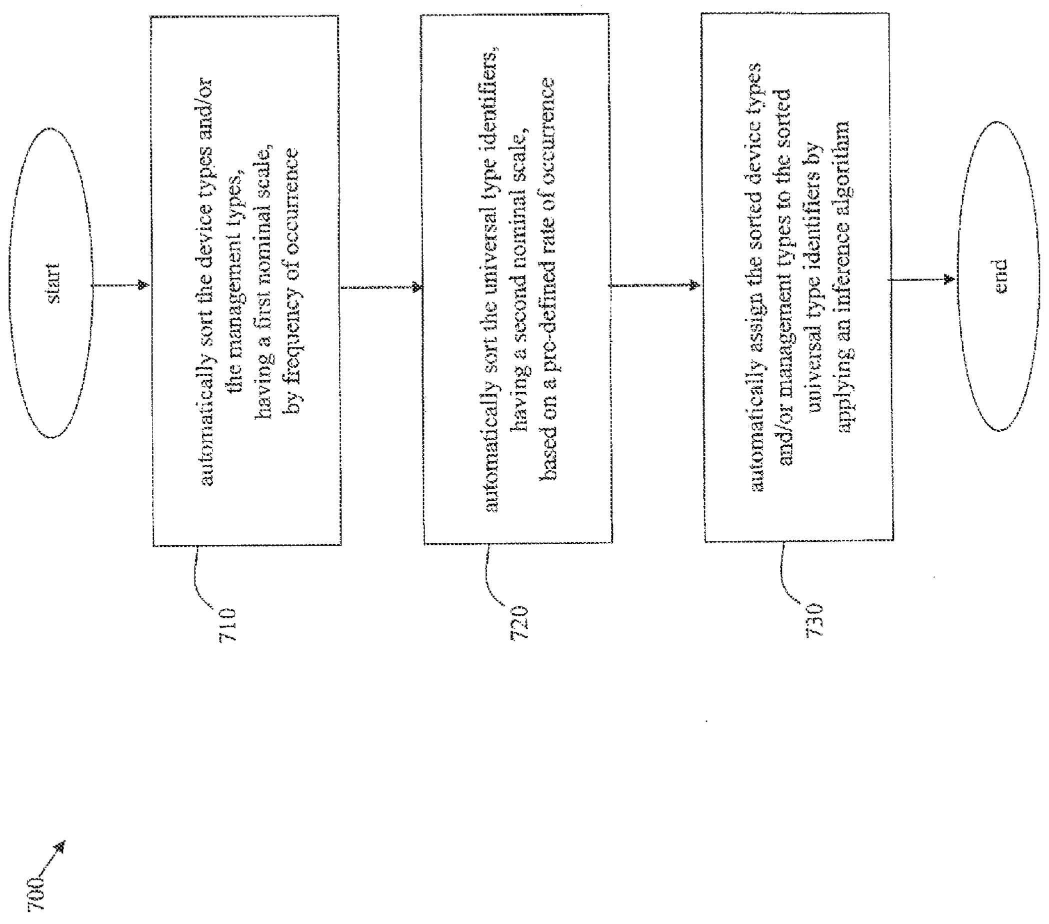

start
automatically sort the device types and/or the management types, having a first nominal scale, by frequency of occurrence
automatically sort the universal type identifiers, having a second nominal scale, based on a pre-defined rate of occurrence
automatically assign the sorted device types and/or management types to the sorted universal type identifiers by applying an inference algorithm
end
710
720
730
700

FIG. 8

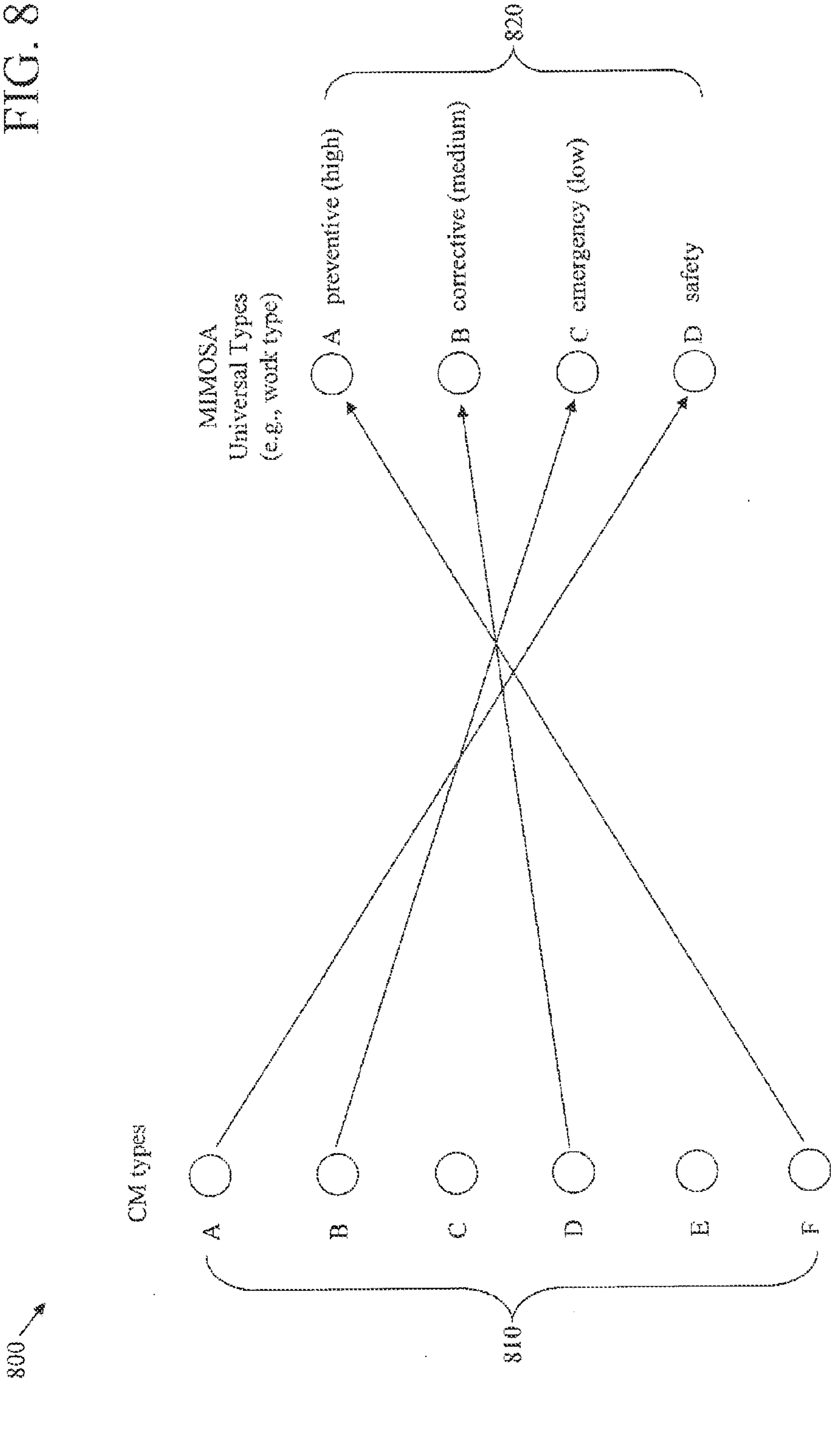
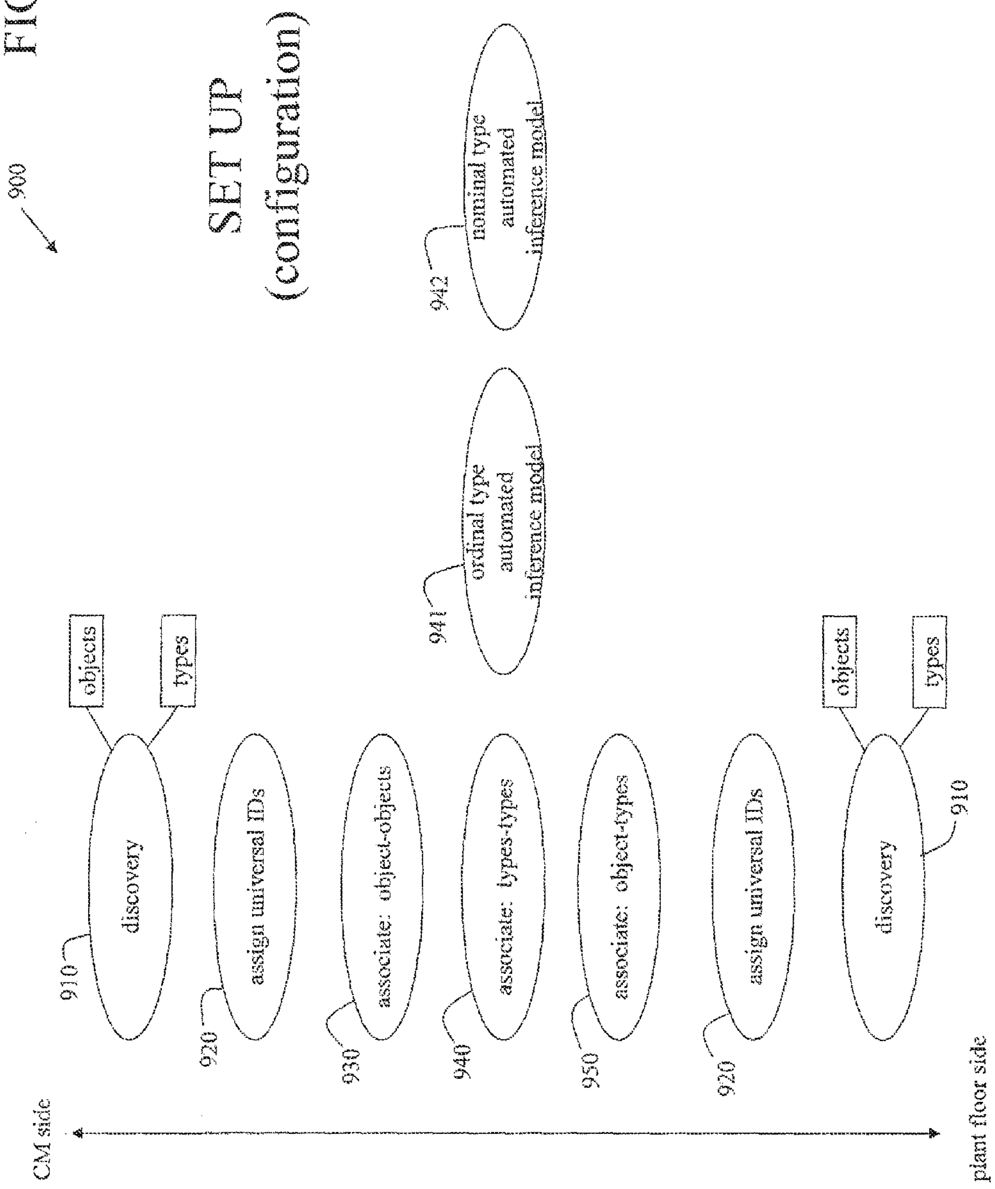

800
CM types
A
B
C
D
E
F
810
MIMOSA
Universal Types
(e.g., work type)
A preventive (high)
B corrective (medium)
C emergency (low)
D safety
820

FIG. 9


900
SET UP
(configuration)
910
discovery
objects
types
920
assign universal IDs
930
associate: object-objects
940
associate: types-types
941
ordinal type
automated
inference model
942
nominal type
automated
inference model
950
associate: object-types
920
assign universal IDs
910
discovery
objects
types
CM side
plant floor side

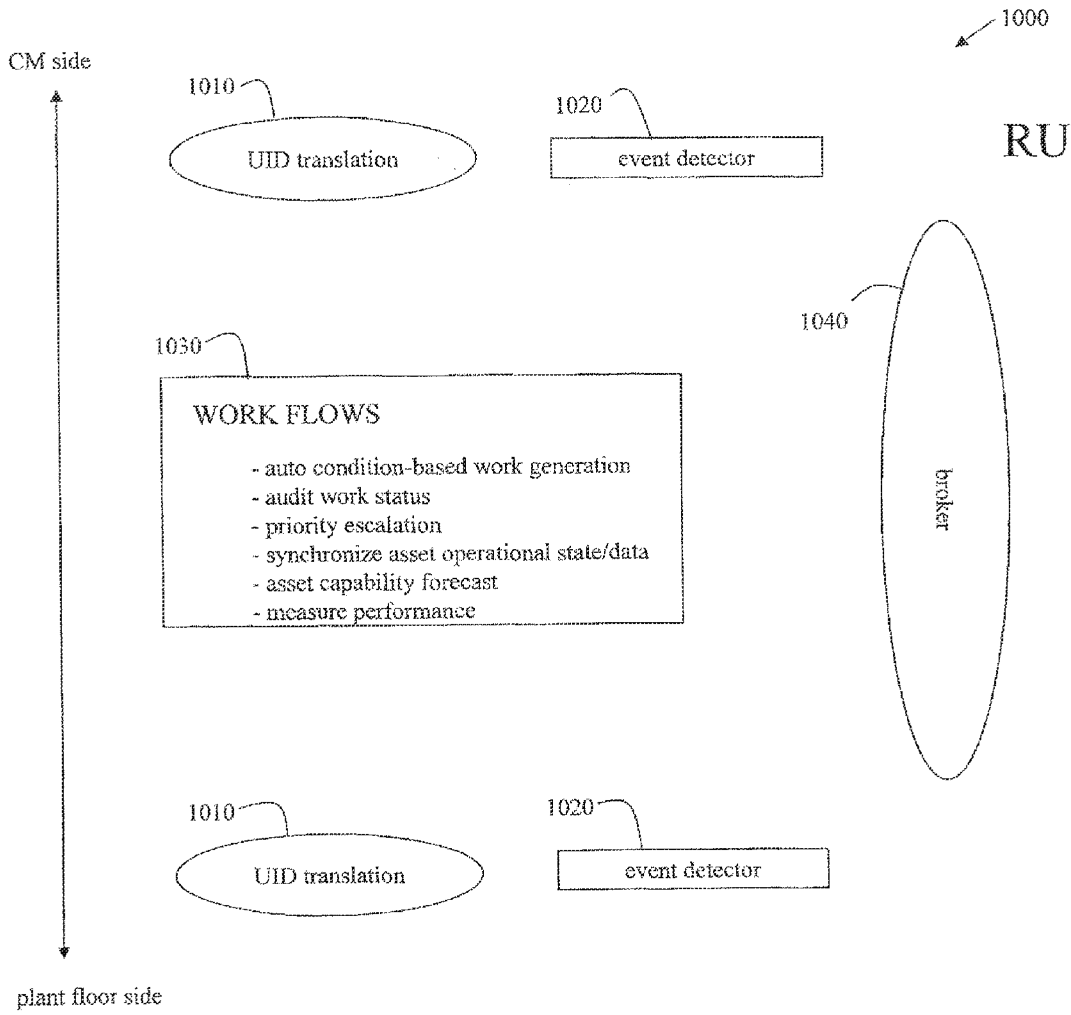


FIG. 10

RUN TIME

SYSTEM AND METHODS FOR THE UNIVERSAL INTEGRATION OF PLANT FLOOR ASSETS AND A COMPUTERIZED MANAGEMENT SYSTEM

This application is a continuation of U.S. application Ser. No. 11/740,404 filed on Apr. 26, 2007, all of which is herein incorporated by reference in its entirety for all purposes.

TECHNICAL FIELD

Certain embodiments of the present invention relate to manufacturing operational and maintenance systems and methods. More particularly, certain embodiments of the present invention relate to a server platform and method for integrating a plurality of diverse, plant floor equipment to at least one computerized management (CM) system by enabling a universal enterprise type taxonomy across the plant floor data sources and the CM system using an open standard.

BACKGROUND

Large manufacturers today face extreme margin pressures from low-cost producers, rising energy costs, and regulatory and environmental restrictions. The need to improve asset performance is very great. One barrier to improvement has been the absence of a performance management solution encompassing the various divisions of operations, maintenance, and finance, for example. With each division using its own performance metrics, it is difficult for optimal decisions to be made, such as balancing reliability goals against asset utilization goals.

Many people have been chasing the "holy grail" of self-diagnostics. Furthermore, there are many balanced scorecards and key performance indicator solutions being offered in today's market. Many seem to be making similar claims including that their product will make a manufacturing process run better, faster, more efficiently, and with greater returns. However, one of the greatest challenges for effectively improving plant asset performance is that the necessary information is scattered across disconnected silos of data in each department. Furthermore, it is difficult to integrate these silos due to several fundamental differences. For example, control system data is real-time data measured in terms of seconds, whereas maintenance cycle data is generally measured in terms of calendar based maintenance (e.g., days, weeks, months, quarters, semi-annual, annual), and financial cycle data is measured in terms of fiscal periods. Furthermore, different vendors of various equipment and enterprise systems tend to have their own set of codes (e.g., status codes) and art non compliant with any universal standard.

An open standard is a standard that is publicly available and has various rights to use associated with the standard. The term "open" is sometimes restricted to royalty-free technologies while the term "standard" is sometimes restricted to technologies approved by formalized committees that are open to participation by interested parties and which operate on a consensus basis. As used herein, the term "open" refers to a standard that is publicly available and that may be used across vendors and customers.

MIMOSA (Machinery Information Management Open Systems Alliance) is an operations and maintenance information open systems alliance organized as a non-profit trade association which includes vendors, integrators and service providers, and end users. MIMOSA collaboratively develops and promotes open standards for operations and maintenance

for fleets, plants, and facilities. MIMOSA produces vendor-neutral open information exchange standards. The MIMOSA open standard provides a common language for vendors to use. However, the MIMOSA standard assumes that every external vendor system is speaking the MIMOSA language, which is not the case today and is not likely to become the case any time soon.

Manufacturers are drowning in a flood of real-time and non-real time data and are losing revenues at the same time. Therefore, there is a growing call for a manufacturing intelligence solution that contextualizes the disparate data in a balanced manner.

Further limitations and disadvantages of conventional, traditional, and proposed approaches will become apparent to one of skill in the art, through comparison of such systems and methods with the present invention as set forth in the remainder of the present application with reference to the drawings.

BRIEF SUMMARY

An embodiment of the present invention comprises a server platform for integrating a plurality of diverse plant floor equipment with at least one computerized management (CM) system. The server platform includes a plurality of plant floor drivers adapted to operationally interface with a plurality of diverse plant floor data sources to at least receive information from the plant floor data sources. The server platform also includes at least one CM system driver adapted to operationally interface with the at least one CM system to at least receive information from the at least one CM system. The server platform further includes a message translator adapted to broker communication between the plant floor data sources and the at least one CM system using an open standard.

Another embodiment of the present invention comprises a method of integrating a plurality of diverse plant floor equipment with at least one computerized management (CM) system. The method includes establishing first communication links between a server platform and a plurality of diverse plant floor data sources via a plurality of plant floor adapters of the server platform to at least receive information from the plant floor data sources. The method further includes establishing a second communication link between the server platform and at least one computerized management (CM) system via at least one CM system adapter of the server platform to at least receive information from the CM system. The method also includes discovering defined device objects and types of the plurality of plant floor data sources via the first communication links and importing the discovered device objects and types into the server platform. The method further includes discovering defined management objects and types of the at least one CM system via the second communication link and importing the discovered management objects and types into the server platform. The method also includes mapping the discovered objects and types to universal identifiers within the server platform, wherein the universal identifiers are defined in an open standard.

A further embodiment of the present invention comprises a system for maintenance and asset management. The system includes a plurality of plant floor data sources adapted to collect data from a plurality of plant floor equipment. The system also includes at least one computerized management (CM) system and a server platform adapted to integrate the plurality of plant floor data sources with the at least one CM system based on a universal enterprise type taxonomy using an open standard.

These and other advantages and novel features of the present invention, as well as details of illustrated embodiments thereof, will be more fully understood from the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic block diagram of an embodiment of a server platform for integrating a plurality of diverse plant floor equipment with at least one computerized management (CM) system;

FIG. **2** is a schematic block diagram of an embodiment of a system for maintenance and asset management using the server platform of FIG. **1**;

FIG. **3** is an exemplary diagram graphically illustrating a discrete mapping of device objects to CM objects.

FIG. **4** illustrates a flowchart of an embodiment of a method of integrating a plurality of diverse plant floor equipment with at least one computerized management (CM) system using the server platform of FIG. **1**;

FIG. **5** illustrates a flowchart of a first embodiment of a method of semantically contextualizing vendor types to universal type identifiers;

FIG. **6** is an exemplary diagram graphically illustrating the method of FIG. **5**;

FIG. **7** illustrates a flowchart of a second embodiment of a method of semantically contextualizing vendor types to universal type identifiers;

FIG. **8** is an exemplary diagram graphically illustrating the method of FIG. **7**;

FIG. **9** is an exemplary diagram graphically illustrating a process for setting up (i.e., configuring) the server platform of FIG. **1** within the system of FIG. **2**; and

FIG. **10** is a diagram graphically illustrating a process for actively running the system of FIG. **2** using the server platform of FIG. **1**.

DETAILED DESCRIPTION

FIG. **1** is a schematic block diagram of an embodiment of a server platform **100** for integrating a plurality of diverse plant floor equipment with at least one computerized management (CM) system for the purpose of maintenance and asset management in an enterprise. The server platform **100** interfaces between plant floor data sources **210** of the plant floor equipment **220** and a computerized management (CM) system **230** (see FIG. **2**), enabling a universal enterprise type taxonomy across the plant floor data sources **210** and the CM system **230** in a manufacturing operational or maintenance environment, for example.

FIG. **2** is a schematic block diagram of an embodiment of a system **200** for maintenance and asset management using the server platform of FIG. **1**. The server platform **100** provides an open standard interface between the plant floor and the CM system. In accordance with an embodiment of the present invention, the server platform provides a common MIMOSA-based interface between the plant floor and the CM system, allowing interoperability between the plant floor and the CM system. The server platform **100** provides the tools and applications to contextualize information and broker communication using the MIMOSA standard vocabulary. Information utilized by the MIMOSA message protocol is organized and communicated using XML, in accordance with an embodiment of the present invention.

The CM system **230** may comprise an enterprise asset management (EAM) system or a computerized maintenance management system (CMMS), for example. Other CM systems are possible as well. The CM system **230** typically acts as a maintenance system but may also encompass other areas such as costs and financials in which executives may have an interest. In accordance with an embodiment of the present invention, more than one CM system may be interfaced to the server platform **100**, even if the CM systems are of differing kinds.

The plant floor equipment **220** may include, for example, motors, compressors, engines, boilers, manufacturing machines, or any other type of equipment that may be found in a plant or factory environment. The plant floor data sources **210** include devices that provide access to operational or measurement data of the plant floor equipment **220**. For example, the plant floor data sources **210** may include on-line condition monitoring devices, process control devices, asset health devices, plant historian devices, transient measurement devices, off-line sampling measurement devices, human-machine interface devices (e.g., for inspection-based expert recommendations), or any other type of devices that collect and output electronic data or information related to the plant floor equipment **220**.

The plant floor equipment **220** and the associated plant floor data sources **210** tend to be of very diverse and disparate types. Also, the CM systems tend to be quite unique in their design and data structures. The server platform **100** provides the integration that allows information collected from such disparate types to be related and effectively used to trigger work flows and generate work orders in the context of the manufacturing operational or maintenance environment. Typically, the server platform **100** is deployed at facility headquarters and connects down to the plant floor systems from there. However, if there is a large volume of equipment at a plant and/or a large geographical distance between the plant and headquarters over a wide area network, then a logical gateway may be installed at the plant acting as a buffer to be able to send data to the server platform **100** at facility headquarters.

Referring again to FIG. **1**, the server platform **100** includes a plurality of plant floor drivers or adapters **110** which allow interfacing of the server platform **100** to the plant floor data sources **210** to transmit and receive information between the server platform **100** and the plant floor data sources **210**. The plant floor drivers/adapters **110** comprise software and/or firmware type drivers/adapters, in accordance with ceratin embodiments of the present invention. The plant floor drivers **110** may support various open communication protocols and various proprietary communication protocols to allow access to various types of real-time data and non-real-time data associated with the plant floor equipment **220**. Examples of some of the plant floor side communication protocols include OPC can open connectivity protocol), modbus, and XML web services. Other communication protocols are possible as well.

In accordance with an embodiment of the present invention, the server platform **100** may be connected to a plant floor data source **210** by entering security credentials and then entering a network identifier and IP address of the data source to which to connect. After connection, the various information (objects and types) from the data source may be pulled into the server platform **100**.

The server platform **100** also includes at least one CM system driver or adapter **120** which allows interfacing of the server platform **100** to at least one CM system **230** to transmit and receive information between the server platform **100** and the CM system **230**. Again, the CM driver/adapter **120** comprises a software and/or firmware type driver/adapter, in accordance with certain embodiments of the present invention. The CM driver/adapter **120** supports a web services protocol, in accordance with certain embodiments of the present invention. For example, in accordance with an embodiment of the present invention, the CM driver/adapter **120** supports the MIMOSA OSA-EAI Tech-XML-services web services protocol.

At the heart of the server platform **100** is a message translator **130**. The message translator **130** acts as a communication broker between the CM system **230** and the plant floor data sources **210** based on a universal type taxonomy. The message translator **130** allows contextualization of received information with metadata and allows mapping of specific vendor types to universal type identifiers. The message translator **130** also allows discrete mapping of specific vendor objects to universal object identifiers. As a result, information and data from both the plant floor side and the CM system side may be associated and related to each other in a meaningful manner such that appropriate work flows may be triggered and such that appropriate work orders may be generated and/or updated to facilitate maintenance and asset management of the enterprise. As used herein, the term vendor refers to the plant floor side and/or the CM system side of the enterprise. At run time, the message translator **130** translates back and forth between the plant floor side and the CM side from an object identifier standpoint and also from a semantic type standpoint.

The message translator **130** includes an open object metadata registry **131** which is a semantic database model. The open object metadata registry **131** includes pre-defined open standard universal identifiers and type taxonomies to which plant floor objects and types and CM system objects and types are associated upon set up or configuration of the server platform **100**. The open object metadata registry **131** also includes various tables which are updated at run time to keep track of conditions such as, for example, status and priority. In accordance with an embodiment of the present invention, the open object metadata registry **131** is based on the MIMOSA standard and, therefore, uses MIMOSA-defined universal object and type identifiers.

The message translator **130** also includes a mapper database **132** which stores the various mappings that occur between plant floor objects and types and universal objects and types, as well as mappings that occur between CM system objects and types and universal objects and types. Again, the universal objects and types are defined by an open standard (e.g., the MIMOSA open standard) and are stored in the open object metadata registry **131**. Types take on a semantic value.

As used herein, the terms vendor objects and types refer to the various information and data that may be collected by the server platform **100** from the plant floor data sources **210** (i.e., device objects and device types) and the CM system **230** (i.e., management objects and management types). The terms open standard objects and types refer to the various universal object and type identifiers or codes defined by the open standard (e.g., MIMOSA object identifiers and MIMOSA type identifiers). By relating the various device objects and types and the various management objects and types to the universal object and type identifiers, a universal enterprise taxonomy may be established across the plant floor data sources **210** and the CM system **230**. By establishing such a universal enterprise taxonomy using such an open standard, a manufacturing intelligence solution that contextualizes the disparate data in a balanced manner is provided.

The mappings stored in the mapper database **132** may include semantic mappings and non-semantic mappings. For example, semantic mappings may include mappings between device types and universal type identifiers, and mappings between management types and universal type identifiers. Furthermore, for example, semantic mappings may include mappings between device objects and universal type identifiers, and mappings between management objects and universal type identifiers. When a vendor type or object is mapped to a universal type ID having a pre-defined semantic meaning, then the mapped vendor type or object has been contextualized.

Non-semantic mappings may include, for example, mappings between device objects and universal object identifiers, and mappings between management objects and universal object identifiers. At run time, the message translator **130** is capable of accessing the mappings to facilitate brokered communication between the plant floor side and the CM system side. Once all of the mappings are complete, then all vendor objects and types that have been mapped are in the same context which is defined by the universal standard (e.g., the MIMOSA standard). The MIMOSA open standard is extensible such that new rows may be added to the MIMOSA tables to support new vendor objects and types that may not conveniently map to a currently defined universal ID.

In accordance with various embodiments of the present invention, the defined objects may include, for example, assets, segments, agents, measurement points, enterprise, and site. An asset is a piece of physical equipment having a serial number. A segment is a logical view of the physical equipment, typically indicating a location of the physical equipment within an enterprise, an agent is a human agent or a software agent that makes an observation, typically providing human intelligence or artificial intelligence capability. Measurement points are outputs of sensors that measure various kinds of equipment parameters such as, for example, temperature and pressure. An enterprise refers to the corporate level of an organization. A site refers to a manufacturing plant, facility, or potentially a fleet object such as a truck which has its own set of segments and assets which may be tracked for maintenance purposes.

In accordance with various embodiments of the present invention, the defined types may include, for example, asset types, work types, priority types, asset priority types, alarm severity types, health types, work priority types, and problem code types. An asset type is a nominal scale type which is a hierarchical categorization of assets based on functional properties, for example “pump” or “seawater pump”. A work type is a nominal scale type which is a categorization of maintenance activities, for example “preventive maintenance” or “corrective maintenance”. An asset priority type is an ordinal scale type for ranking the relative importance of the asset. An alarm severity type is an ordinal scale type for ranking the relative importance of the severity of the alarm. A health type is a nominal scale type for indicating the type of health advisory, for example “vibration analysis” or “instrumentation alert”. A work priority type is an ordinal scale type for ranking relative importance of work, for example “high” or “low”. A problem code type is a nominal scale type which is a categorization of problems that can impact the health of assets, for example “mechanical failure” or “electrical failure”.

Referring again to FIG. **1**, the server platform **100** includes various software applications that reside in and run on the server platform **100** to provide various types of functionality. The various software applications shown in FIG. **1** may be discrete applications or may be combined in certain ways, in accordance with various embodiments of the present invention. In the discovery phase of set up, the server platform **100** detects plant floor monitoring systems and picks up device definitions within the plant floor monitoring systems. Similarly, the server platform **100** detects CM systems and picks up asset definitions within the CM systems. The server platform **100** includes a discovery application **140** adapted to automatically discover and import defined device objects and types from the plant floor data sources **210** via the plant floor driver/adapters **110**, and adapted to automatically discover and import defined management objects and types from the CM system **230** via the CM system driver/adapter **120**. The discovery application **140** is used during set up for configuring of the server platform **100** with particular plant floor data sources **210** and a particular CM system **230**.

The server platform **100** also includes a semantic mapping or contextualizing application **150** adapted to semantically map the discovered management types to pre-defined open standard universal type identifiers, and adapted to semantically map certain device types to the pre-defined open standard universal type identifiers. When a device type gets mapped to a universal type U), and a CM system type gets mapped to the same universal type ID, then the device type and the CM system type become related via the common universal type ID. Furthermore, certain device objects may get mapped to certain management types. When a device object gets mapped to a management type, the device type "inherits" all of the type information of the management type. Examples of such semantic mappings are described below herein with respect to FIGS. **5**-**8**.

The server platform **100** further includes an assigning application **160** adapted to assign first universal object identifiers to the device objects and second universal object identifiers to the management objects. The server platform **100** also includes a non-semantic mapping application **170** adapted to non-semantically map the first universal object identifiers to the second universal object identifiers, thereby relating the device objects to the management objects.

The MIMOSA open standard defines the format of the universal IDs that are used for non-semantic assignments. Such non-semantic assignments may be used simply for trackability and traceability purposes.

The server platform **100** further includes a manual mapping application tool **175** allowing for a user to manually accomplish semantic and/or non-semantic mappings. Such manual mappings may be performed to refine automatic mappings performed by the server platform **100**, or to accomplish mappings that are not automatically handled by the server platform **100**.

In accordance with an embodiment of the present invention, the system **200** includes a graphic user interface **240** operationally interfacing to the server platform **100** and adapted to allow a user to manage, for example, MIMOSA-based mappings between defined device objects and types imported from the plant floor data sources **210** and the defined management objects and types imported from the CM system **230** using the manual mapping application tool **175**. The graphic user interface **240** may be used for other purposes as well such as, for example, allowing a human operator to manually input information into the system **200**.

For example, referring to FIG. **3**, a CMMS system may provide a CMMS defined object **310** being a motor definition having a string, a serial number, and an object identifier in a proprietary format for the CMMS vendor. The CMMS object **310** may be assigned to a single universal object identifier **320** by the assigning application **160** of the server platform **100**. Similarly, there may be five sensors on the plant side corresponding to five different device objects **330** each measuring a different parameter of the same actual motor on the plant floor. Each of the five device objects **330** may correspond to a different sensor measurement or reading for the motor. Each of the five device objects **330** may have a string and a tag identifier and get assigned to five different universal object identifiers **340** by the assigning application **160** of the server platform **100**.

The non-semantic mapping application **170** may then automatically map the five universal object identifiers **340** corresponding to the five device objects **330** to the single universal object identifier **320** corresponding to the CMMS object **310**, thereby relating the five sensors of the plant floor motor to the CMMS motor object and storing this mapping in the mapper database **132**. Therefore, at run time (i.e., during operation of the system **200**), rule-based work flows may be triggered and work orders may be generated for the motor in response to any of the five sensor measurements. As an alternative, the manual mapping application tool **175** may be used by an operator, via the graphic user interface **240**, to manually perform the mapping. As a result, there are five children UIDs mapped to one parent UID to establish the relationship between the CMMS motor definition and the five plant floor sensor outputs.

Non-semantic mappings may be many-to-one, as in the above example, or one-to-one. For example, for a compressor definition in the CM system, there could be a number of condition monitoring sensors which are fed into a plant historian. When the mappings are created, connections are defined between the plant floor tags (each of which correspond to a sensor in this example) and the asset definitions in the CM system. The server platform **100** may automatically discover and enumerate the entities from the plant floor systems, however, the mapping/association to the CM system via the universal open standard may require manual input.

The server platform **100** may further may include a condition-based maintenance application **180** adapted to generate maintenance work orders in response to information collected from the plant floor data sources **210** and the CM system **230**. Certain kinds of maintenance work order include predictive maintenance work orders, preventive maintenance work orders, corrective maintenance work orders, and emergency maintenance work orders. For example, the condition-based maintenance application **180** may monitor a lower level condition point of a plant floor valve providing temperature and vibration information. If the temperature exceeds 100° C. and the vibration level exceeds a threshold value INB and the valve status is "open", then a work order may be generated to, for example, shut down the valve and/or have the valve inspected.

As an option, the server platform **100** may also include a performance measurement application **190** adapted to track key performance indicators in response to information collected from the plant floor data sources **210** and the CM system **230**. The performance measurement application **190** tracks key performance indicators in the form of score cards, in accordance with an embodiment of the present invention. Such applications **180** and **190** process and analyze data put information in a human intelligible form.

For example, a key performance indicator (KPI) may be the overall facility maintenance cost as a percentage of die overall facility equipment replacement cost. If the cost to maintain the facility equipment is greater than the cost to replace the facility equipment, then it is likely that too much maintenance is being performed at the facility. Such a key performance indicator is determined by the performance measurement application **190** after extracting and relating the relevant information from the CM system side and the plant floor side. A lower level KPI may be pulled up into a higher level KPI, for example, such that the higher level KPI may be used by an executive at headquarters.

As an option, the server platform **100** may include a software development kit (SDK) **195** which is an API programming tool kit that allows vendors to communicate messages to call an appropriate method and direct the SDK **195** to perform an appropriate mapping. Such an SDK **1.95** allows a vendor to have more direct control over the mapping outcomes.

FIG. **4** illustrates a flowchart of an embodiment of a method **400** of integrating a plurality of diverse plant floor equipment **220** with at least one computerized management (CM) system **230** using the server platform **100** of FIG. **1** in step **410**, establish first communication links **215** between the server platform **100** and a plurality of diverse plant floor data sources **210** via a plurality of plant floor adapters **110** of the server platform **100** to at least receive information from the plant floor data sources **210**. In step **420**, establish a second communication link **235** between the server platform **100** and at least one computerized management (CM) system **230** via at least one CM system adapter **120** of the server platform **100** to at least receive information form the CM system **230**. In step **430**, discover defined device objects and types of the plurality of plant floor data sources **210** via the first communication links **215** and import the discovered device objects and types into the server platform **100**. In step **440**, discover defined management objects and types of the at least one CM system **230** via the second communication link **235** and import the discovered management objects and types into the server platform **100**. Di step **450**, map the discovered objects and types to universal identifiers within the server platform **100**, wherein the universal identifiers are defined in an open standard. In accordance with an embodiment of the present invention, the open standard is the MIMOSA open standard. The method **400** is accomplished during a set up time or a configuration time for the server platform **100**.

The mapping of step **450** may include semantically contextualizing the device types and the management types to pre-defined open standard universal type identifiers within the server platform **100**. Also, the mapping of step **450** may include assigning the device objects and the management objects to globally unique identifiers (universal object identifiers) within the server platform **100**. Furthermore, the mapping of step **450** may include semantically associating the management objects to universal type identifiers within the server platform **100**. The mapped universal identifiers are stored within the mapper database **132** of the server platform **100**.

Again, the CM system **230** may include an enterprise asset management (EAM) system, a computerized maintenance management system (CMMS), or some other type of computerized management system. The first communication links **215** are adapted to use at least one of open communication protocols and proprietary communication protocols such as an open connectivity protocol, a modbus protocol, an XML web services protocol, or some particular proprietary protocol, for example. The second communication, link **235** is adapted to use a web services protocol such as, for example, the MIMOSA OSA-EAI Tech-XML-services web services protocol.

In accordance with an embodiment of the present invention, the device types may include at least one of alarm severity types, asset criticality types, health types, problem types, failure types, and remedy types. Similarly, the management types may include at least one of asset types, work priority types, asset criticality types, health types, problem types, failure types, and remedy types.

Once the server platform **100** is configured using the method **400** of FIG. **4**, the entire system **200** may be run such that the server platform **100** brokers communication between the plant floor data sources **210** and the CM system **230** using the stored mapped universal identifiers. The server platform **100** may poll certain measurement points every so often and pull the data into the server platform via the drivers/adapters. Also, there may be one or more dedicated real-time connections to the server platform **100** such that the server platform **100** is continuously pulling in real-time data. Furthermore, an asset health vendor may use the SDK **195** to push messages into the server platform **100** by writing code against the API of the SDK.

One or more work flows may be triggered in response to the brokered communication during run time of the system **200**. In general, a particular work flow is triggered when a certain set of conditions occur. For example, the various kinds of work flows that may be triggered include an audit work status work flow, an escalate priority work flow, a synchronize asset data work flow, a production asset capability threcast work flow, and a measure performance work flow (score carding). A work flow is similar to a state machine operation and includes a set of steps that occur over time and often involve human interaction. At run time, a work flow routes messages to the appropriate system end points.

For example, an alert or alarm may be detected for a piece of equipment on the plant floor that has a problem and requires attention. In response to the detected alert, a work flow is triggered and a work order is generated, having a first priority, in the CM system to go and inspect that piece of equipment (Le, that asset). If two weeks pass, and there is no record in the CM system that the inspection has occurred, then the priority may be escalated by opening the work order and increasing the priority of the work order and triggering a work flow in the CM system which will flag the situation to the maintenance committee to make sure action is taken immediately. Similarly, if a more critical alert occurs, the priority of the work order may be escalated. However, to escalate priority, the system **200** must understand the semantic meaning within the CM system for the corresponding priority code. The semantic mappings provide this meaning and allows rules for escalating priority and for checking work order status to be processed.

As another example of a work flow, with respect to synchronization of data, a valve may be installed on the plant floor and the valve is detected by one of the lower level plant device monitoring systems (i.e., a plant floor data source) such as a device manager. When the server platform **100** determines that the valve has been installed on the plant floor, the server platform **100** may check within the CM system to determine if such a valve has already been defined. If not, the corresponding valve definition can be automatically generated and mapped (semantically and/or non-semantically).

As a further example, an asset health system (a particular kind of plant floor data source) may detect a degradation in the health of a certain piece of plant floor equipment. The asset health system may push a message “create work order” to the server platform **100**. As a result, a work flow is triggered within the server platform **100** in response to the message. The server platform **100** checks if there is already a work order open and, if so, if the status of the work order is “opened” or “closed”. If the status of the work order is “closed”, another work order may be generated. If the status of the work order is “open”, the priority of the work order may be escalated.

FIG. **5** illustrates a flowchart of a first embodiment of a method **500** of semantically contextualizing vendor types to universal type identifiers. In step **510**, automatically sort the device types and/or the management types, having a first ordinal scale, by ordinality. In step **520**, automatically sort the universal type identifiers, having a second ordinal scale, by ordinality. In step **530**, automatically assign the sorted device types and/or management types to the sorted universal type identifiers by applying an inference algorithm.

FIG. **6** is an exemplary diagram **600** graphically illustrating the method **500** of FIG. **5**. The diagram **600** illustrates how CM types **610**, being priority types and having an ordinal scale of 1 to 6, have been sorted by ordinal number from lowest priority 1 to highest priority 6. The CM types **610** may correspond to the priority of a corrective maintenance work order, for example. The diagram **600** also illustrates how MIMOSA universal types **620**, also being priority types and having a different ordinal scale of 1 to 4 (low, medium, high, very high), have been sorted by ordinal number from lowest priority 1 to highest priority 4. An automated inference algorithm is used to perform the semantic contextualization mapping from the CM types **610** to the MIMOSA universal types **620** as shown by the arrows.

In this example, the automated inference algorithm applies a histogram technique that allows mapping from one ordinal scale to another. The histogram technique results in CM types 1 and 2 being mapped to MIMOSA universal type 1 (low priority), CM type 3 being mapped to MIMOSA universal type 2 (medium priority), CM type 4 being mapped to MIMOSA universal type 3 (high priority), and CM types 5 and 6 being mapped to MIMOSA universal type 4 (very high priority). Therefore, the six priority types on the CM side have been successfully mapped (in a semantically contextualized manner) to the four priority types defined by the MIMOSA open standard. In accordance with an embodiment of the present invention, the sorting and mapping is performed by the semantic mapping application **150** of the server platform **100**.

FIG. **7** illustrates a flowchart of a second embodiment of a method **700** of semantically contextualizing vendor types to universal type identifiers. In step **710**, automatically sort the device types and/or the management types, having a first nominal scale, by frequency of occurrence. In step **720**, automatically sort the universal type identifiers, having a second nominal scale, based on a pre-defined rate of occurrence. In step **730**, automatically assign the sorted device types and/or management types to the sorted universal type identifiers by applying an inference algorithm.

FIG. **8** is an exemplary diagram **800** graphically illustrating the method **700** of FIG. **7**. The diagram **800** illustrates how CM types **810**, being work types and having a nominal scale of A to F, have been sorted by frequency of occurrence from highest (A) to lowest (F). The CM types **810** may correspond to the different maintenance work types, for example. The diagram **800** also illustrates how MIMOSA universal types **820**, also being work types and having a different nominal scale of A to D (preventive-high, corrective-medium, emergency-low, and safety), have been sorted based on a pre-defined rate of occurrence. The pre-defined rate of occurrence may be determined from an actual work order history that has been accumulated and stored in the server platform **100** or in the CM system **230**. An automated inference algorithm is used to perform the semantic contextualization mapping from the CM types **810** to the MIMOSA universal types **820** as shown by the arrows.

In this example, the automated inference algorithm applies a heuristic probability technique that allows mapping from one nominal scale to another. The heuristic probability technique results in CM type A being mapped to MIMOSA universal type 1) (safety), CM type B being mapped to MIMOSA universal type C (emergency-low), CM type D being mapped to MIMOSA universal type B (corrective-medium), and CM type F being mapped to MIMOSA universal type A (preventive-high). Therefore, our of the six work types on the CM side have been successfully mapped (in a semantically contextualized manner) to the four work types defined by the MIMOSA open standard. Two of the CM types C and E apparently do not semantically fit into any of the four MIMOSA universal types A to D and, therefore, have not been mapped. Such CM work types C and E may not be used by the server platform **100** in the system **200**, or may be handled in a separate manner by the server platform **100**. Again, in accordance with an embodiment of the present invention, the sorting and mapping is performed by the semantic mapping application **150** of the server platform **100**.

FIG. **9** is an exemplary diagram **900** graphically illustrating the process for setting up (i.e., configuring) the server platform **100** of FIG. **1** within the system **200** of FIG. **2**. Discovery **910** of objects and types is performed both on the CM side and the plant floor side. Assigning **920** of universal identifiers is performed, both on the CM side and the plant floor side, to objects and types. Non-semantic association **930** of CM objects and device objects is performed. Contextualized semantic type association **940** of CM types and device types is performed. The semantic type associations may be performed using an ordinal type automated inference model **941**, a nominal type automated inference model **942**, or some other interference model (not shown). Furthermore, contextualized semantic type association **950** of objects and types is performed.

FIG. **10** is a diagram **1000** graphically illustrating the process fbr actively running the system **200** of FIG. **2** using the server platform **100** of FIG. **1**. As data and information are received by the server platform **100** from both the plant floor side and the CM side, the server platform **100** performs universal identifier (UID) translations **1010** based on the mappings that were generated during set up and stored in the mapper database **132**. Events are detected **1020** within the server platform **100** in response to the translated data and information, and work flows **1030** are triggered in response to the detected events **1020**. Also, the server platform **100** brokers communications **1040** between the CM side and the plant floor side to accomplish work flows and to generate work orders.

In accordance with an embodiment of the present invention, the server platform **100** may extract information from the CM system **230** and send the extracted information to the plant floor side to be rendered or displayed via a portal on the plant floor side. For example, work history status or priority information may be extracted and rendered in this manner. In general, the CM system **230** may transmit hack events that occur to the plant floor for non-control purposes. Such events include change events such as, for example, a change in a work status. For example, a planned overhaul message may be sent from the CM system to an asset health system on the plant floor. As a result, the asset health system will know not to send out a plurality of predictive work orders, for example, because the associated plant floor equipment will be getting shut down to perform the planned overhaul.

In summary a server platform and a method to integrate a plurality of diverse plant floor equipment with at least one computerized management system in a manufacturing operational or maintenance system are disclosed. The server platform, using an open standard, enables a universal enterprise type taxonomy across the plant floor data sources and the at least one computerized management system, providing a manufacturing intelligence solution that contextualizes the disparate data in a balanced manner.

While the invention has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

The invention claimed is:

1. A server platform for integrating a plurality of diverse plant floor equipment with at least one computerized management (CM) system, said server platform comprising:

- a processor;
- a memory;
- a plurality of plant floor drivers adapted to interface with a plurality of diverse plant floor data sources so as to receive at least first information from said plurality of plant floor data sources;
- at least one CM system driver adapted to interface with said at least one CM system so as to receive at least second information from said at least one CM system;
- a discovery application adapted to:
  - automatically discover and import, from a first data source of said plurality of diverse plant floor data sources via said plant floor drivers, at least one of a first device object of a plurality of defined device objects and a first device type of a plurality of defined device types, and
  - automatically discover and import, from said at least one CM system via said CM system driver, at least one of a first management object of a plurality of defined management objects and a first management type of a plurality of defined management types;
- one or more mapping applications configured to generate mappings by performing at least one of:
  - mapping said first device object to a first universal identifier of a plurality of universal identifiers,
  - mapping said first device type to said first universal identifier,
  - mapping said first management object to said first universal identifier, thereby relating at least one of said first device object and said first device type to said first management object, and
  - mapping said first management type to said first universal identifier, thereby relating at least one of said first device object and said first device type to said first management type; and
- a message translator adapted to, based on said mappings, associate portions of the first information from said first plant floor data source with portions of the second information from said at least one CM system.

2. The server platform of claim **1** wherein said message translator includes a semantic model forming an open object metadata registry capable of enabling a universal enterprise type taxonomy across said plant floor data sources and said at least one CM system.

3. The server platform of claim **1** further comprising a mapper database adapted to store semantic mappings and non-semantic mappings between said plant floor data sources and said CM system such that said message translator is capable of accessing said mappings to facilitate said message translator to associate said portions of first and second information.

4. The server platform of claim **1** wherein said CM system comprises one of a computerized maintenance management system (CMMS) and an enterprise asset management (EAM) system.

5. The server platform of claim **1** wherein said plant floor data sources include at least one of an asset health system, condition monitoring sensors, and a plant historian system.

6. The server platform of claim **1** wherein said universal identifiers are defined in an open standard and said open standard comprises the MIMOSA open standard.

7. The server platform of claim **1** further comprising a contextualizing application adapted to semantically map said plurality of defined management types to pre-defined open standard universal type identifiers and adapted to semantically map said plurality of defined device types to said pre-defined open standard universal type identifiers.

8. The server platform of claim **1** further comprising an assigning application adapted to assign first universal object identifiers to said plurality of defined device objects and second universal object identifiers to said plurality of defined management objects.

9. The server platform of claim **8** wherein a first mapping application of the one or more mapping applications is adapted to non-semantically map said first universal object identifiers to said second universal object identifiers, thereby relating said plurality of defined device objects to said plurality of defined management objects.

10. The server platform of claim **1** wherein said plurality of defined device and/or management objects comprise at least one of assets, segments, agents, measurement points, enterprise, and site.

11. The server platform of claim **1** wherein said plurality of defined device and/or management types comprise at least one of asset types, work types, priority types, asset priority types, alarm severity types, ordinal health types, work priority types, and problem code types.

12. The server platform of claim **1** further comprising a condition based maintenance application adapted to generate maintenance work orders in response to said first information collected from said plant floor data sources and said second information collected from said at least one CM system.

13. The server platform of claim **1** further comprising a performance measurement application adapted to track key performance indicators in response to said first information collected from said plant floor data sources and said second information collected from said at least one CM system.

14. The server platform of claim **1** wherein communication with said plurality of plant floor data sources is accomplished via at least one of open communication protocols and proprietary communication protocols.

15. The server platform of claim **1** wherein communication with said at least one CM system is accomplished via a web services protocol.

16. A method of integrating a plurality of diverse plant floor equipment with at least one computerized management (CM) system, said method comprising:

- establishing, via a plurality of plant floor adapters of a server platform, first communication links between said server platform and a plurality of diverse plant floor data sources so as to receive at least first information from said plant floor data sources;
- establishing, via at least one CM system adapter of said server platform, a second communication link between said server platform and at least one computerized management (CM) system so as to receive at least second information from said CM system;

discovering, via said first communication links, at least one of a first device object of a plurality of defined device objects and a first device type of a plurality of defined device types from a first data source of said plurality of plant floor data sources;

importing at least one of said first device object and said first device type into said server platform;

discovering, via said second communication link, at least one of a first management object of a plurality of defined management objects and a first management type of a plurality of defined management types from said at least one CM system and importing at least one of said first management object and said first management type into said server platform; and

performing at least one of:

mapping said first device object to a first universal identifier of a plurality of universal identifiers,

mapping said first device type to said first universal identifier,

mapping said first management object to said first universal identifier, thereby relating at least one of said first device object and said first device type to said first management object, and

mapping said first management type to said first universal identifier, thereby relating at least one of said first device object and said first device type to said first management type.

17. The method of claim **16** wherein said mapping includes semantically contextualizing said plurality of defined device types and said plurality of defined management types to predefined open standard universal type identifiers within said server platform.

18. The method of claim **16** wherein said mapping includes assigning said plurality of defined device objects and said plurality of defined management objects to globally unique identifiers within said server platform.

19. The method of claim **16** wherein said mapping includes semantically associating said plurality of defined management objects to universal type identifiers within said server platform.

20. The method of claim **16** wherein said CM system comprises one of a computerized maintenance management system (CMMS) and an enterprise asset management (EAM) system.

21. The method of claim **16** wherein said first communication links are adapted to use at least one of open communication protocols and proprietary communication protocols.

22. The method of claim **21** wherein said protocols include at least one of an open connectivity protocol, a modbus protocol, an XML, web services protocol, and a proprietary protocol.

23. The method of claim **16** wherein said second communication link is adapted to use a web services protocol.

24. The method of claim **23** wherein said web services protocol includes a MTM:OSA OSA-EAI Tech-XML-services web services protocol.

25. The method of claim **16** wherein said plurality of defined device and/or management objects include at least one of assets, segments, agents, measurement points, enterprise, site.

26. The method of claim **16** wherein said plurality of defined device and/or management types include at least one of asset types, work types, priority types, asset priority types, alarm severity types, ordinal health types, work priority types, and problem code types.

27. The method of claim **16** wherein said plurality of defined device types include at least one of alarm severity

types, asset criticality types, health types, problem types, failure types, and remedy types.

28. The method of claim **16** wherein said plurality of defined management types includes at least one of asset types, work priority types, asset criticality types, health types, problem types, failure types, and remedy types.

29. The method of claim **16** further comprising storing said mapped universal identifiers within said server platform.

30. The method of claim **29** further comprising associating portions of the first information from said plant floor data sources with portions of the second information from said at least one CM system using said stored mapped universal identifiers.

31. The method of claim **16** wherein said universal identifiers are defined in an open standard and said open standard comprises the MIMOSA open standard.

32. The method of claim **30** further comprising automatically triggering a least one work flow in response to said associated portions.

33. The method of claim **32** wherein said work flow comprises at least one of an audit work status work flow, an escalate priority work flow, a synchronize asset data work flow, a production asset capability forecast work flow, and a measure performance work flow.

34. The method of claim **30** further comprising automatically generating at least one work order in response to said associated portions.

35. The method of claim **34** wherein said work order comprises an automated condition-based maintenance work order.

36. The method of claim **35** wherein said automated condition-based maintenance work order comprises at least one of a predictive maintenance work order, a corrective maintenance work order, a preventive maintenance work order, and an emergency maintenance work order.

37. The method of claim **30** further comprising automatically tracking at least one key performance indicator in response to said associated portions.

38. The method of claim **17** wherein said semantic contextualizing includes:

automatically sorting said plurality of defined device types and/or said plurality of defined management types, having a first ordinal scale, by ordinality;

automatically sorting said universal type identifiers, having a second ordinal scale, by ordinality; and

automatically assigning said sorted device types and/or said sorted management types to said sorted universal type identifiers by applying an inference algorithm.

39. The method of claim **38** wherein said inference algorithm, includes a histogram technique.

40. The method of claim **17** wherein said semantic contextualizing includes:

automatically sorting said plurality of defined device types and/or said plurality of defined management types, having a first nominal scale, by frequency of occurrence;

automatically sorting said universal type identifiers, having a second nominal scale, based on a pre-defined rate of occurrence; and

automatically assigning said sorted device types and/or said sorted management types to said sorted universal type identifiers by applying an inference algorithm.

41. The method of claim **40** wherein said inference algorithm includes a heuristic technique.

42. The method of claim **40** wherein said frequency of occurrence is determined from a work history stored within said server platform.

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